Space Weather Technical Forecast

Issued on Monday, 25 September 2023 at 13:15 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Isolated M-flares likely, with a slight chance of X-flares (R1-R3 Radio blackouts). Chance of G1-G2 minor/moderate geomagnetic storms Days 1 and 2 (25-26 Sep).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate with a single M-flare observed in the past 24hrs, peaking at M1.0 at 24/1500 UTC from the AR3443 region in the southeast. Frequent C-flares were also observed, some long lasting. There are 10 sunspot regions on the visible disc, with one unnumbered. AR3445 was the most active and developmental region on the disc, with ongoing flux emergence leading to a persistent small delta spot on its southern edge. AR3443 in the northwest and AR3435 in the west-centre disc have persisted as moderately sized regions, with AR3443 seeing continued activity from a small reverse polarity trailing spot. AR3435 remains notable with a small delta spot on its northern portion, but activity has been quiet. A newly numbered region, AR3447, lies to the southeast of AR3445, and has been quick to form. It is currently in a beta magnetic configuration, and has already seen some activity so will be a region to keep an eye on. The other new region, as yet unnumbered, is rotating around the northeastern limb.

A number of eruptions were observed over the western limb, but are considered to be far-sided with no significant Earth component, pending further analysis. A long period C9.8 flare peaking at 25/0813 from the AR3447 region saw some dimming on imagery and may result in a possible CME, this will be looked at once relevant coronagraph imagery comes in. No other Earth-directed CMEs have been observed in the past 24hrs.

Solar Wind / Geomagnetic Activity: Slow wind conditions persisted for much of 24 Sep before a CME arrived during the UTC evening. Speeds increased from background to slightly elevated, 300 km/s becoming 470 km/s. The density followed a similar pattern, rising from below average to briefly well above average, with a peak of around 60 ppcc at 24/2033 UTC. It has since reduced slightly to average to above average. The Interplanetary magnetic field strength (IMF), Bt, was initially weak before becoming strong, around 28nT at 24/2043 UTC. It saw another slight rise to very strong from 25/0615 UTC, remaining around 33nT. The north-south component (Bz) also rose from weak to negatively strong (peaking at -28nT at 24.2043 UTC), but has since become predominantly positive and very strong, peaking at -33nT at 25/0800 UTC. Phi angle was predominantly positive (away from the Sun), then became predominantly negative after 24/2000 UTC, before switching back to positive from around 25/0730 UTC. Resultant geomagnetic activity was Quiet to Unsettled (Kp 1-3) at first, with G1/G2 Minor/Moderate Storm (Kp5-6) intervals between 24/1800-25/0600 UTC. Activity dropped back to Unsettled/Active levels from 25/0600 UTC.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux was at background to moderate levels. GOES16 high energy (greater than 2MeV) electron flux was moderate until 24/2045 UTC when it became background due to a CME arrival. Associated

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24-hour fluence was below the Active (1e8 integrated pfu) threshold and on a declining trend. The observation at 24/0001 UTC was 1.4e7 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Forecast to persist at Moderate with further isolated M-flares likely, and a slight chance of rising to High due to the potential for isolated X-flares from AR3445 in the south.

Solar Wind / Geomagnetic Activity: Ongoing impacts from a CME arrival on 24 Sep remain likely through the first part of Day 1 (25 Sep). Further CME arrivals are possible into Day 2 (26 Sep). Confidence is low however, with glancing impacts most likely. The slightly elevated solar winds are expected to continue through Day 1 (25 Sep), likely easing thereafter to slow ambient.

Geomagnetic activity is likely to remain Active (Kp4) initially with G1/G2 Minor/Moderate storming (Kp5-6) possible. Geomagnetic activity should then reduce back to Unsettled to Active (Kp3-4) with a chance of further G1/Minor storm intervals should any subsequent glancing CMEs occur into Day 2 (26 Sep). Quiet to Unsettled (Kp1-3) activity is then expected to dominate toward the end of the forecast period.

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is expected to remain at Background levels, with a daily slight chance of an enhancement should any larger flares occur.

High energy electron flux (greater than 2MeV) has become background due to a CME arrival on 24 Sep. Further CME glancing blows may continue this trend, though confidence reduces later in the period with a chance or returning to high by Day 4 (28 Sep). The associated 24 hour fluence is in a declining phase and will likely remain below the Active threshold until at least Day 4 (28 Sep), though any increase is low confidence.

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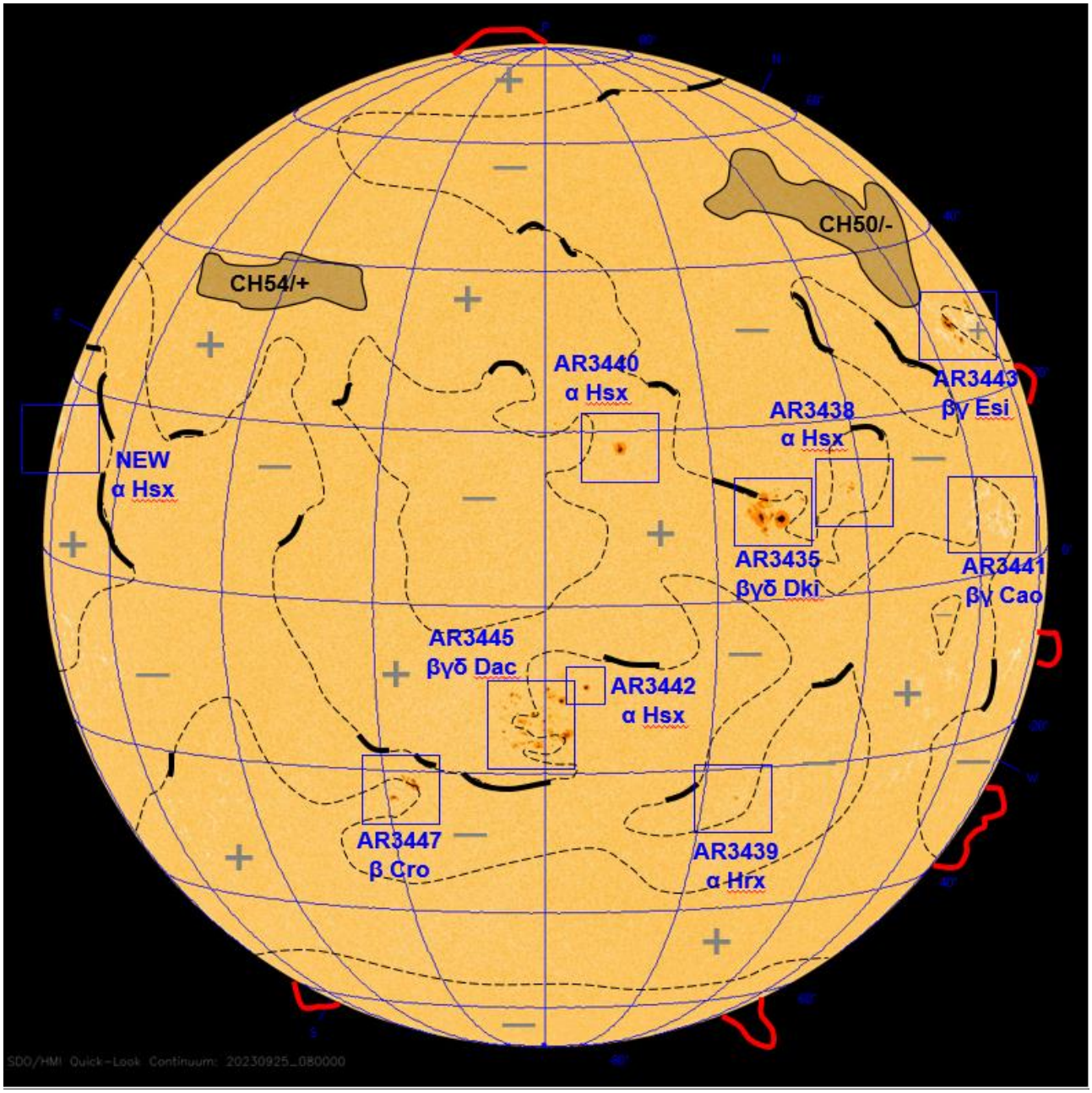
Figure 1. Solar Analysis Valid 25/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

The geomagnetic forecast is currently low confidence due to the number of CME's that have recently left the Sun. The CME associated with the long period M1.2 flare from 22/0336 UTC is thought to have arrived late 24 Sep. This may have swept up and combined with other CMEs from 20 Sep and 21 Sep. Ongoing impacts from this arrival is expected during Day 1 (25 Sep).
There remains the potential for arrivals from two further CMEs from early on 22 Sep. The first from south of the AR3435/38 complex spot, and a further one to the north of this region. These are both weak eruptions but give a slight chance of further enhancements on Days 1-2 (25/26 Sep) but these are very low confidence. Other CMEs which feature in the forecast are from the double peak M1.5/1.4 flare at 22/1621 UTC and 22/1714 UTC of AR3443 in the northwest and from the M1.9 flare at 22/2300 UTC from AR3435/38. These CMEs are currently expected to be missing Earth but may give slight glancing impacts, potentially combined within the material in the aforementioned CMEs.

Further CMEs were observed leaving the Sun from the western limb on 24 Sep. Most appear to be far-sided, with a suggestion one could give a weak glancing blow late on Day 4 (Sep 28), pending further analysis.

Overall this gives a very low confidence geomagnetic forecast. Active levels (Kp4) are likely, with G1/G2 Minor/Moderate geomagnetic storming (Kp5-6) possible, for Days 1-2 (25-26 Sep) due to the ongoing CME arrival, as well as any other glancing blows from other CMEs mentioned above. Beyond this into Days 3-4 (27-28 Sep) the effects of these CMEs is expected to wane, with solar winds also expected to decrease and a return to Quiet to Unsettled levels (Kp1-3). A further enhancement is possible late on Day 4 with another glancing CME, but this is very low confidence at this point.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	50	30	20	10
Strong	G3	No	10	5	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
22/1134	Partial	Filament	34N 13W	592 km/s	Late 25/26 Sep	Missing/glancing
22/1504	Partial	Filament	21S 12W	497 km/s	Late 25/26 Sep	Missing/glancing

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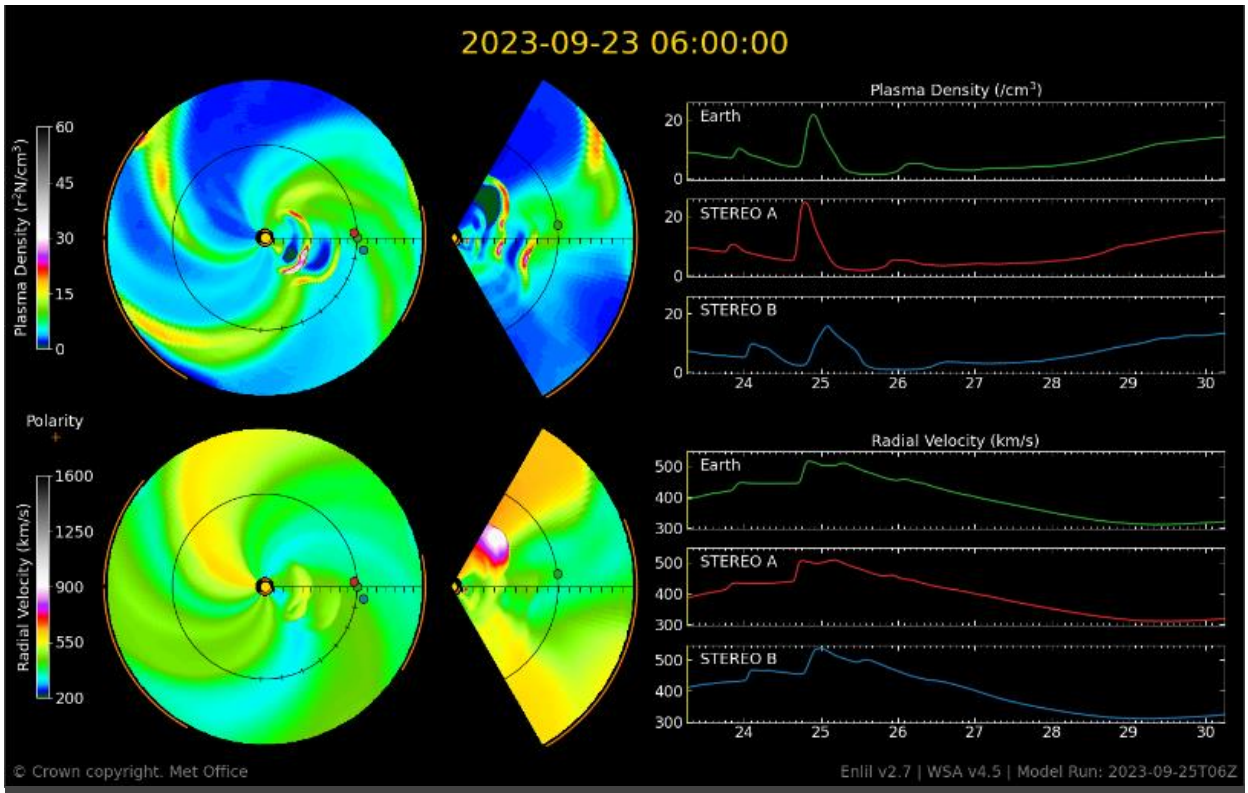
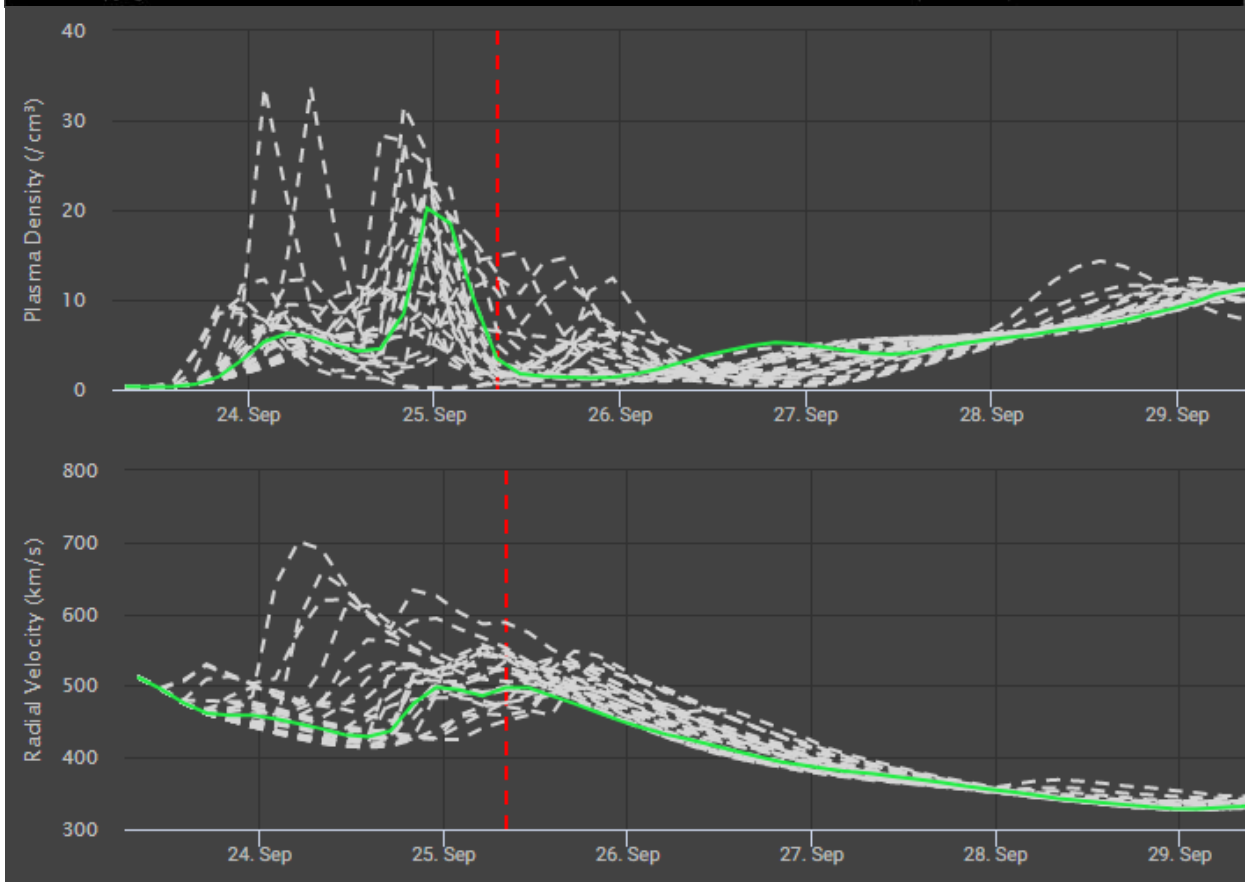
Figure 2: Enlil and ensemble showing sequence of possible CME arrivals





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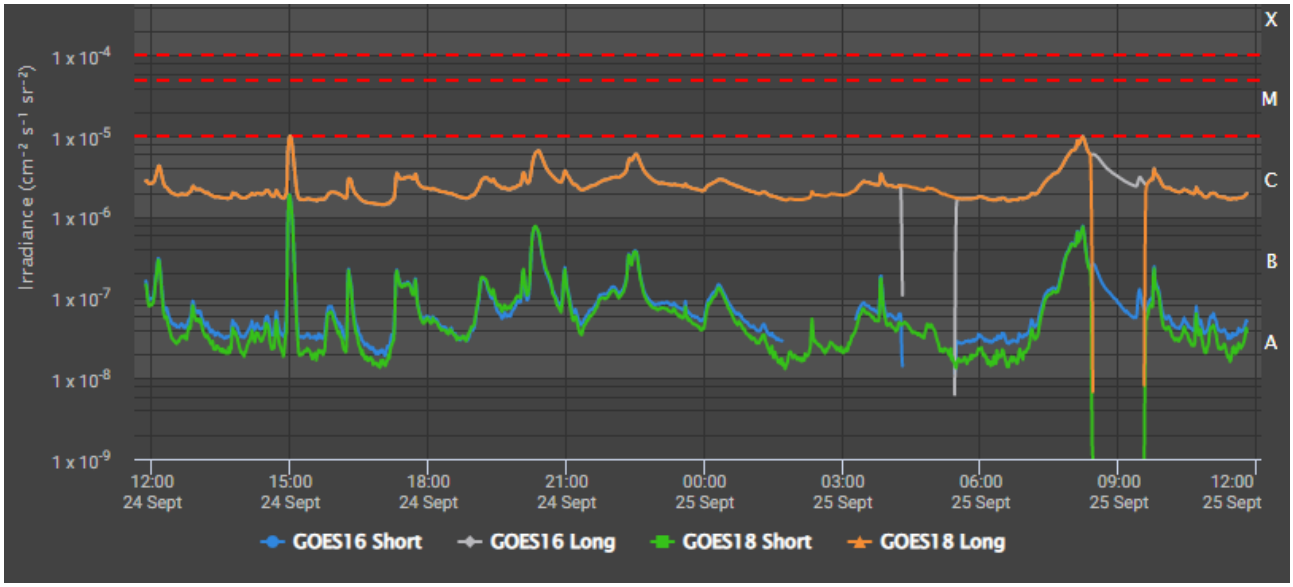
Radio Blackouts - X-Ray Flares:
Moderate activity is expected with an ongoing likelihood of further M-flares through the period, and a slight chance of rising to High with the potential for isolated X-flares. This is due to the current number of spots (ten) and the complexity of at least two.

AR3445 in the southeast quadrant has a small mixed polarity region, with a potentially unstable delta configuration on its southern edge. AR3435 and AR3443 both remain larger regions. AR3435 in the west perhaps remains the more notable of these two, at least magnetically, with a delta spot in its northern portion, but has been fairly quiet. AR3443 has been the more active, with a reverse polarity spot that formed close to its trailing spots being the source for a number of flares. The newly numbered region AR3447 has formed to the southeast of AR3445, growing quickly with some recent flare activity, and will be a region to keep an eye on if it continues to grow.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	70	70	60	60
Very Active	R3 to R5 X Class	No	20	20	15	10

Figure 3: GOES 16 and 18 X-ray flux



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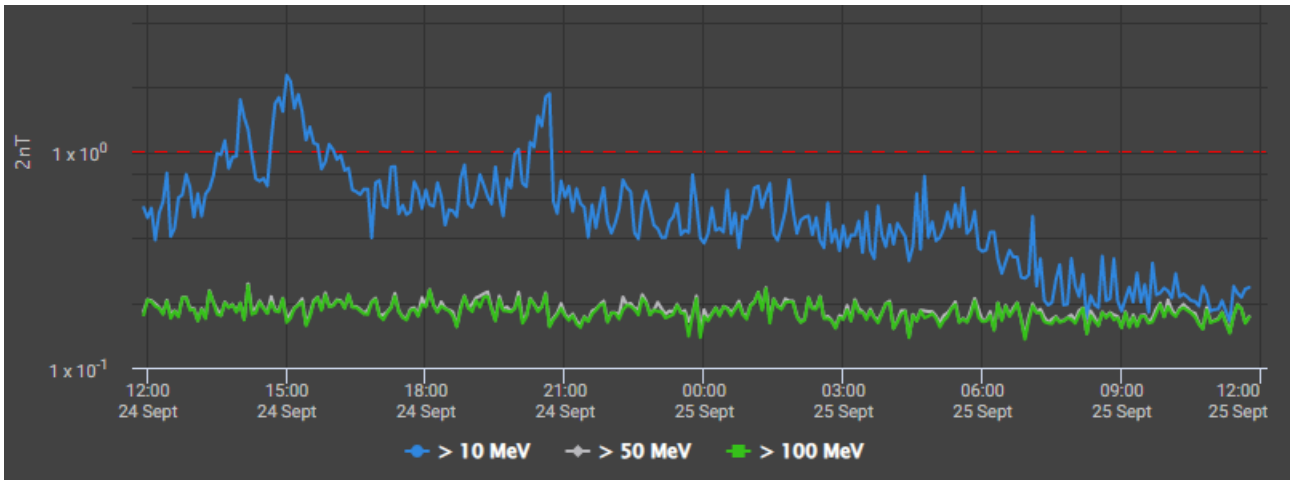
Solar Radiation Storms - (High Energy Protons):
The high energy (greater than 10MeV) proton flux observed by GOES16 is likely to persist at background to moderate levels, however there are regions either on, or moving onto the western disc which bring a chance of flux levels rising above background given the occurrence of any significant flares. This includes AR3443 and AR3435, as well as AR3445 in the south.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	15	15	10	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: GOES 16 Proton flux



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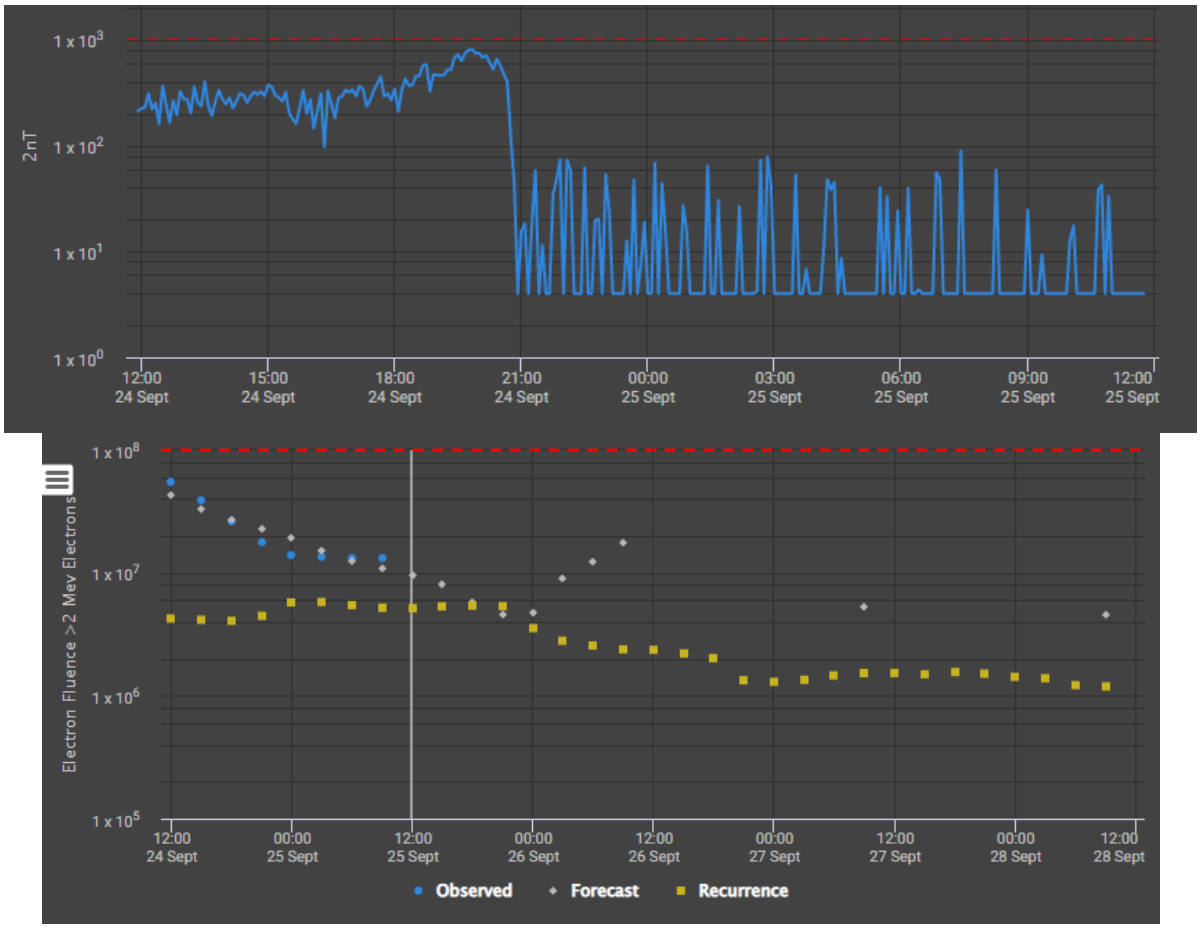
High Energy Electrons Event (≥ 2MeV):
High energy electron flux (greater than 2MeV) observed by GOES16 has been largely moderate, as enhanced electron levels at lower orbits expand outward to GEO. The CME arrival on 24 Sep has since reduced electron counts and is likely to continue to do so through Day 1 and perhaps into Day 2 (25/26 Sep). Further CME glancing blows may continue this trend, though confidence reduces later in the period with a chance or returning to high by Day 4 (28 Sep).

The associated 24 hour fluence is in a declining phase and will likely remain below the Active threshold until at least Day 4 (28 Sep), though any increase is low confidence. REFM is currently giving good guidance of the expected trend, remaining below Active throughout.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	5	5	10	20
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 5: GOES 16 Electron flux and associated fluence with REFM



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